Residential Water and Energy Savings in Right-Sized Premise Plumbing

By
Toritseju Omaghomi and Steven Buchberger
WDSA CCWI Kingston Canada.
July 23rd, 2018

ED_002522A_00000124-00001

Outline

- Introduction
  - Motivation
  - Objective
- Method
    - Variable 1: Fixture Efficiency
    - Variable 2: Pipe Sizing Method
    - Variable 3: Pipe Layout
  - WDC – Water Demand Calculator
  - PRP – Poisson Rectangular Pulse
  - EPANET – EPA Network
- Results
- Conclusion

Introduction

Research Question:

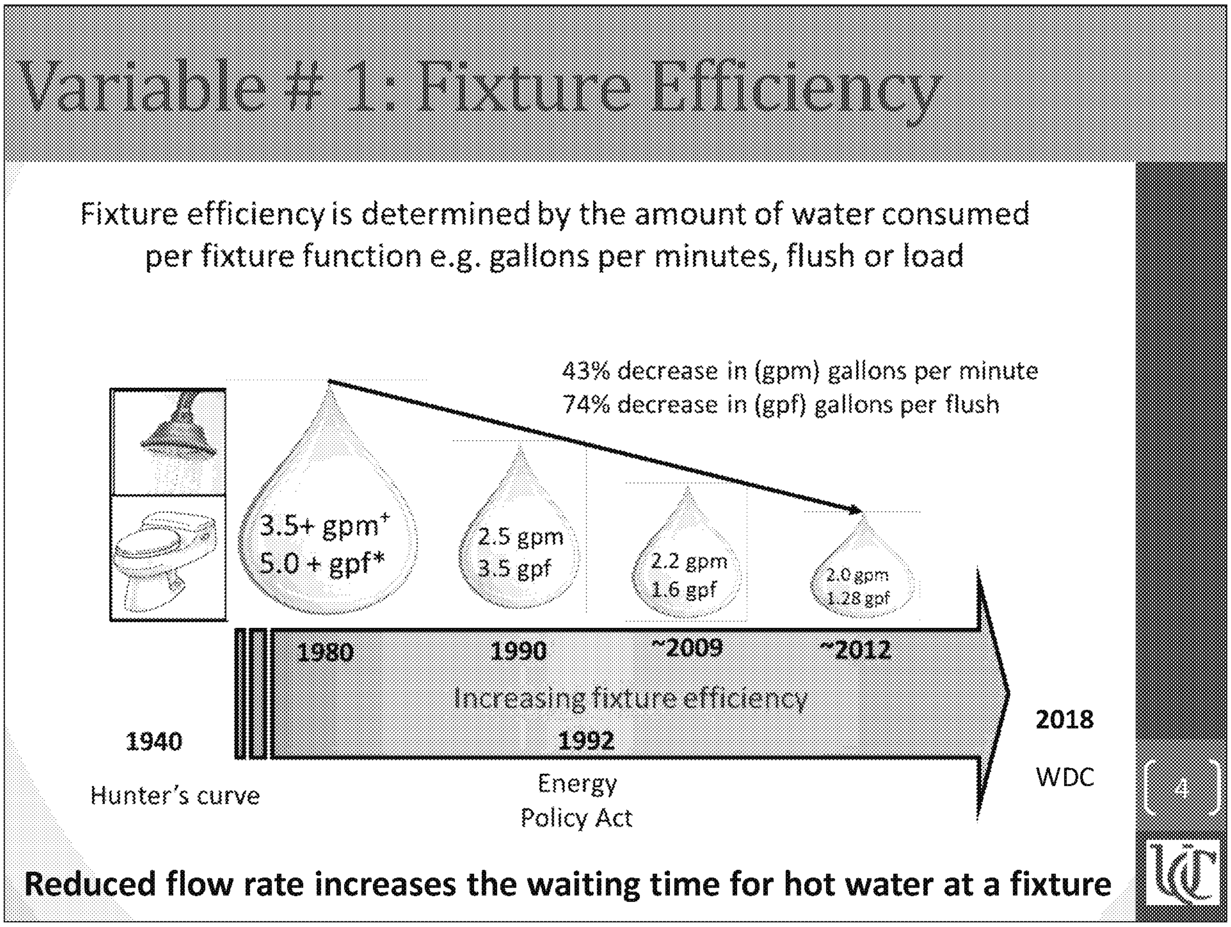
What is the combined effect of low flow fixtures, reduced pipe size and pipes layout on residential energy consumption relative to hot water use?

Objective:

Quantify water and energy savings in residential buildings resulting from efficient (water-conserving) fixtures.

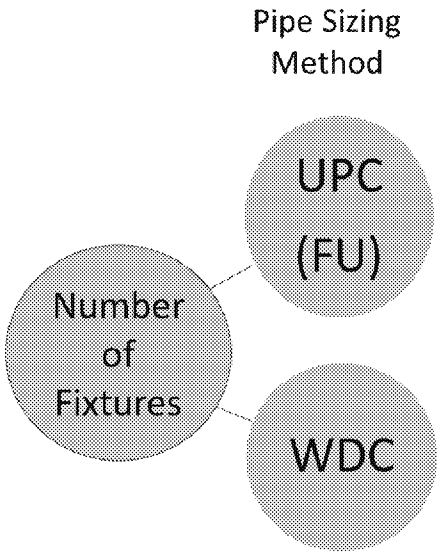
Reduced flow rate decreases overall water use
Smaller pipes decreases wasted water/energy (Hot water distribution)
Pipe layout/fixture location affect the amount of heat delivered to a fixture

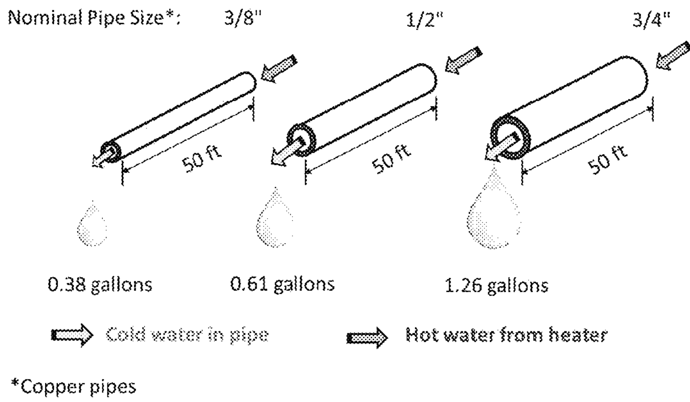
Recent research on hot water distribution system has considered the following factors relative to hot water energy consumption: fixture flow rates, pipe size, pipe material (Klein 2013), pipe layout (Hiller 2012; Klein 2013) and hot water waste at different fixtures (Lutz 2005; Lutz et al. 2014).



Define fixture efficiency

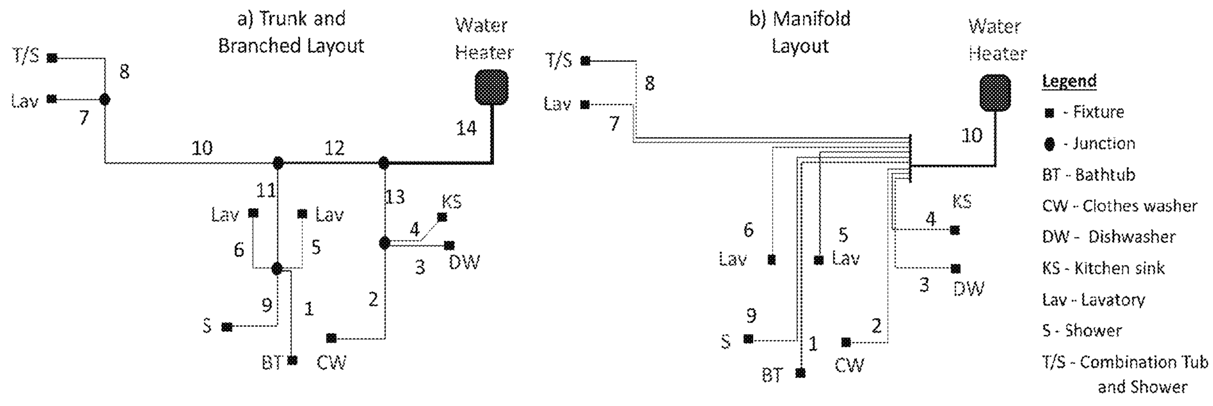
Variable # 2: Pipe Sizing Method





- Reduced flow rate increases the waiting time for hot water at a fixture.
- **Pipe size determines the volume of water in the pipes.**

Variable # 3: Pipe Layout

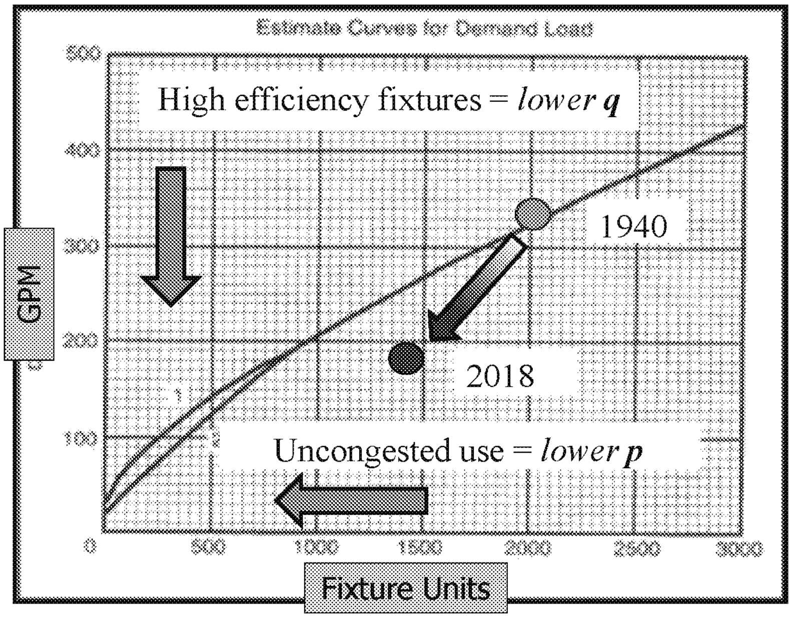


- Reduced flow rate increases the waiting time for hot water at a fixture.
- Pipe size determines the volume of water in the pipes.
- **Combined pulse characteristics from multiple fixtures and pipe layout.**

6

Combined pulse characteristics from multiple fixtures and pipe layout

Hunter's Curve (1940)



- Today, **Hunter's curve** is often faulted for giving overly conservative design….Why?

Combine the 99th percentile demand from different fixtures with different flow signatures into a single curve.

Developed in 1940

Withstood the test of time

Basis for plumbing codes around the globe today

It is clever, convenient and correct.

WDC: Estimate Peak Demand & Size Pipe

↓ Select Units ↓

Monday, 18 June, 2018 12:06 PM

PROJECT NAME : XXX-XXX

GPM LPM LPS

FIXTURE GROUPS		[A] FIXTURE	[B] ENTER NUMBER OF FIXTURES	[C] PROBABILITY OF USE (%)	[D] ENTER FIXTURE FLOW RATE (GPM)	[E] MAXIMUM RECOMMENDED FIXTURE FLOW RATE (GPM)
Bathroom Fixtures	1	Bathtub (no Shower)	0	1.0	5.5	5.5
	2	Bidet	0	1.0	2.0	2.0
	3	Combination Bath/Shower	0	5.5	5.5	5.5
	4	Faucet, Lavatory	0	2.0	1.5	1.5
	5	Shower, per head (no Bathtub)	0	4.5	2.0	2.0
	6	Water Closet, 1.28 GPF Gravity Tank	0	1.0	3.0	3.0
Kitchen Fixtures	7	Dishwasher	0	0.5	1.3	1.3
	8	Faucet, Kitchen Sink	0	2.0	2.2	2.2
Laundry Room Fixtures	9	Clothes Washer	0	5.5	3.5	3.5
	10	Faucet, Laundry	0	2.0	2.0	2.0
Bar/Prep Fixtures	11	Faucet, Bar Sink	0	2.0	1.5	1.5
Other Fixtures	12	Fixture 1	0	0.0	0.0	6.0
	13	Fixture 2	0	0.0	0.0	6.0
	14	Fixture 3	0	0.0	0.0	6.0

Total Number of Fixtures 0

99th PERCENTILE DEMAND FLOW = GPM

RESET

RUN WATER DEMAND CALCULATOR

↑ CLICK BUTTON ↑

8

Found at: http://www.iapmo.org/Pages/WaterDemandCalculator.aspx

Selects from 4 methods based on a combination of fixture count and probability of use.

This determines the peak hour demand for pipe sizing

Blues cell – given

White cells – Input

Green Cells - Output

PRP: Arrival at Fixtures & Demand Pulses

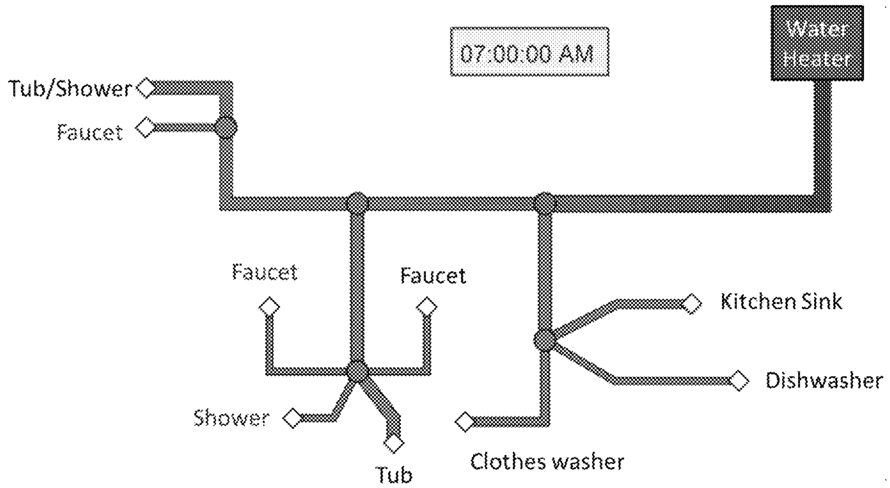
- Poisson Rectangular Pulse (PRP) method (Buchberger and Wu 1995)
  - Simulates arrival time at fixture as a Poisson process
- Ensure there are no overlapping pulses at individual fixtures
- Fixture flowrate and duration of use are based on fixtures in IAPMO database (Inefficient or efficient)

9

Simulates instantaneous water use at fixture on a 1 seconds timescale for 24 hour a day and 365 days

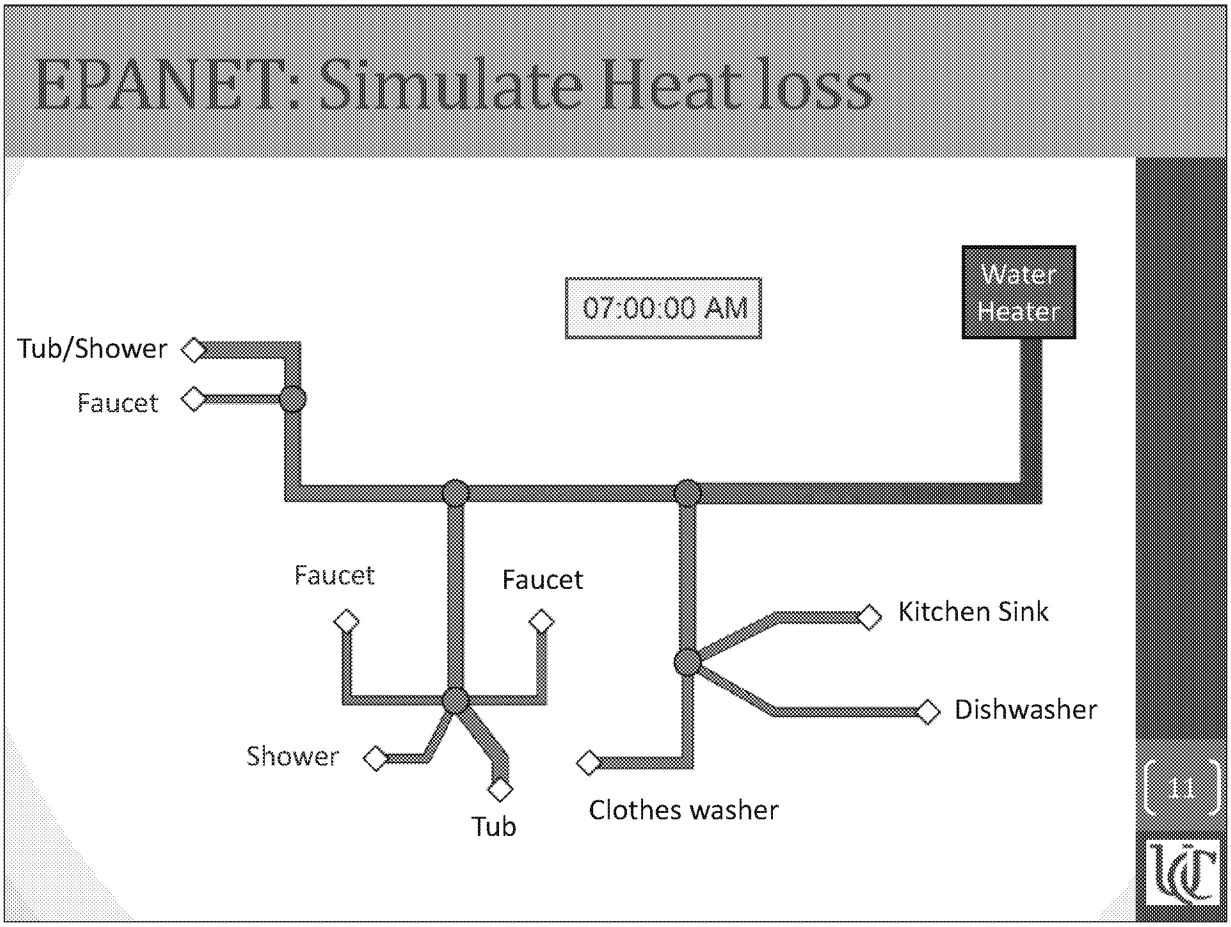
EPANET: Simulate Heat loss

- Input
  - Fixture base flow
  - Fixture multipliers generated from pulses
  - Heat loss rate for Copper L pipe



10

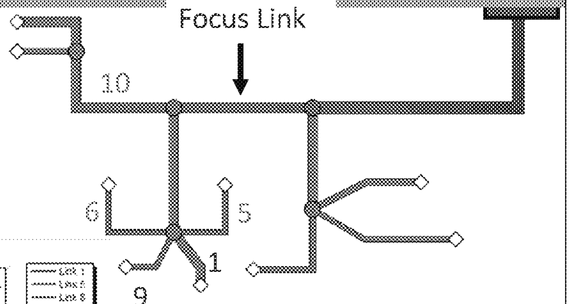
EPANET public domain hydraulic software to simulate water distribution between treatment plants and streets
Option applied is used to simulated water quality
This the 1st application of EPANET to simulate thermal properties for 24 hour period

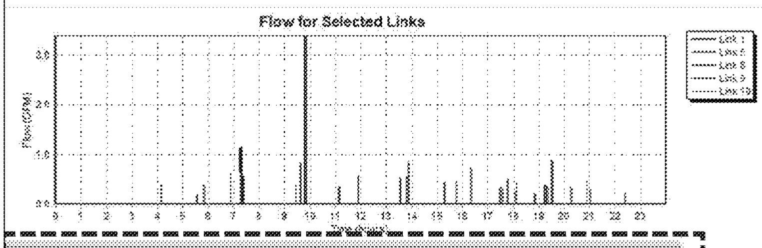


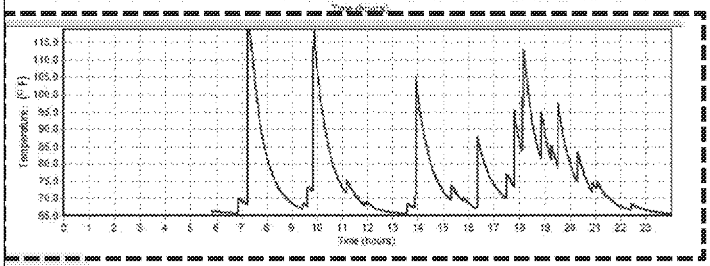
One hour window with 3 pulses
Turns green for flow
10 seconds
1 minute no flow

EPANET: Simulate Heat loss

- Output
  - Heat loss in pipes with time







24 Hour Heat loss in Focus Link

Heat loss rate for copper L pipe:

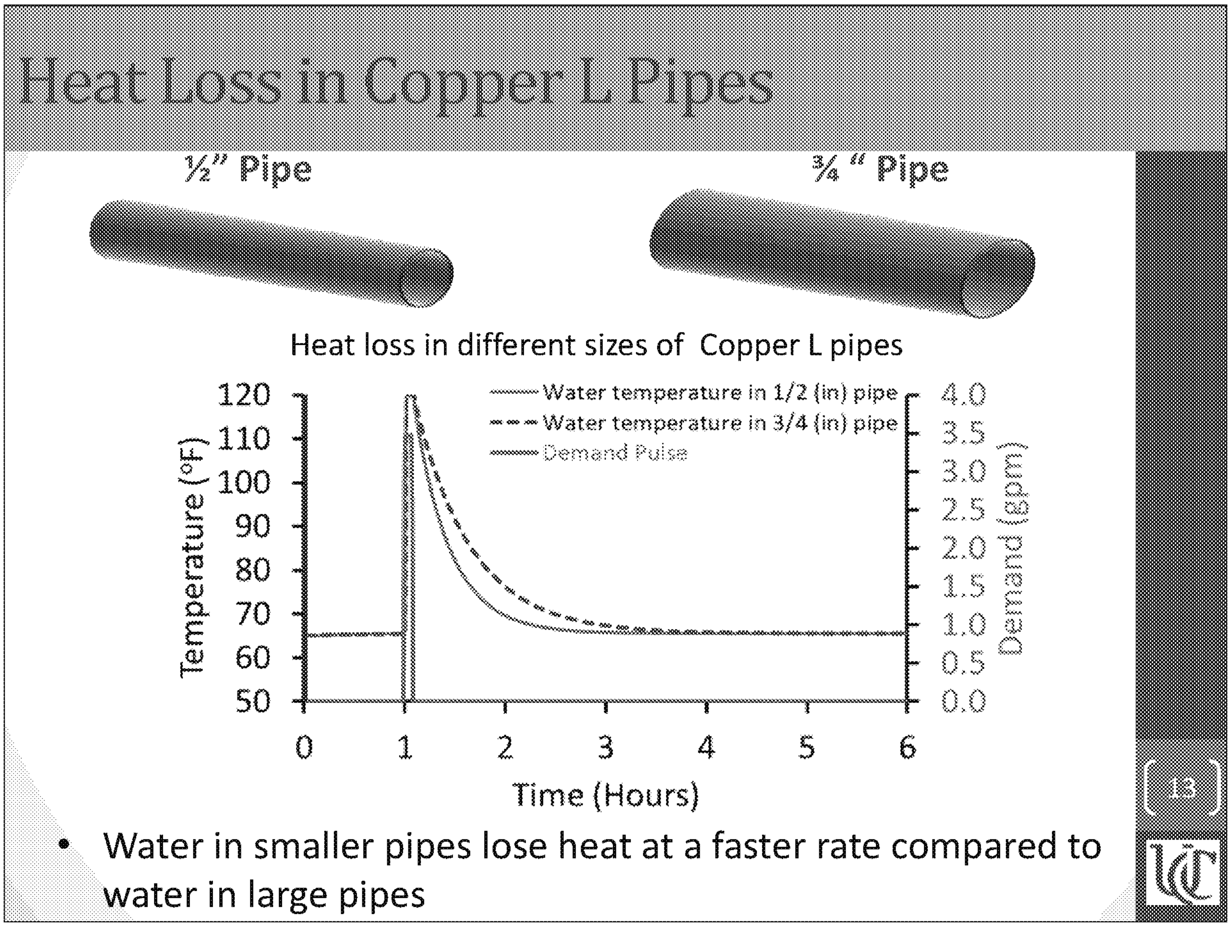
Combine
Heat capacity formula

$Q = mc\Delta T$

and
Heat transfer formula

$Q = \frac{kA\Delta T}{d}$

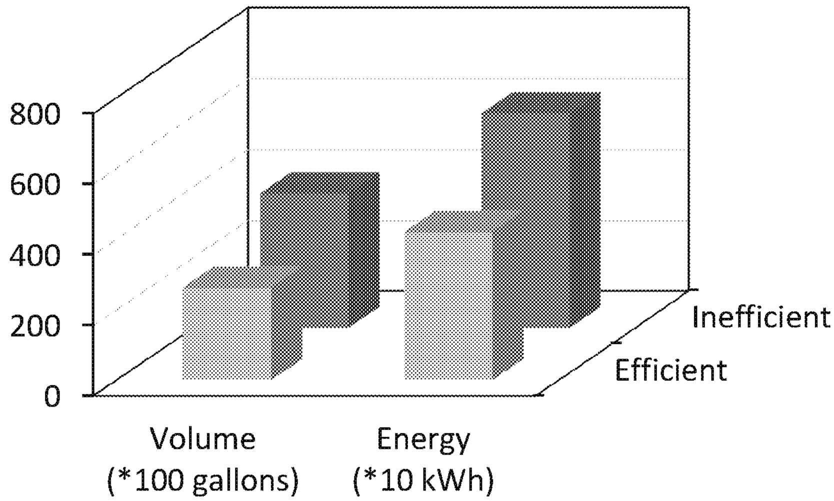
EPANET public domain hydraulic software to simulate water distribution between treatment plants and streets
Option applied is used to simulated water quality
This the 1st application of EPANET to simulate thermal properties for 24 hour period



Example of different pipe sizes and the rate at which they cool The smaller pipe has less resistance to heat transfer, and the volume of water is spread thin in uninsulated pipes

Results: Variable #1 – Fixture Efficiency

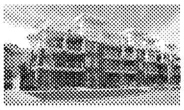
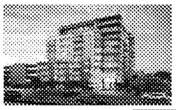
30 % decrease in the annual volume of hot water consumed **=** 30 % decrease in the annual energy consumed



For example, **Pre-retrofitted** 2 bath single family home with **inefficient fixtures** vs **Post-retrofitted** 2 bath single family home with **efficient fixtures**, both having a trunk and branched layout

Retrofitted buildings Before and after efficient fixture installation

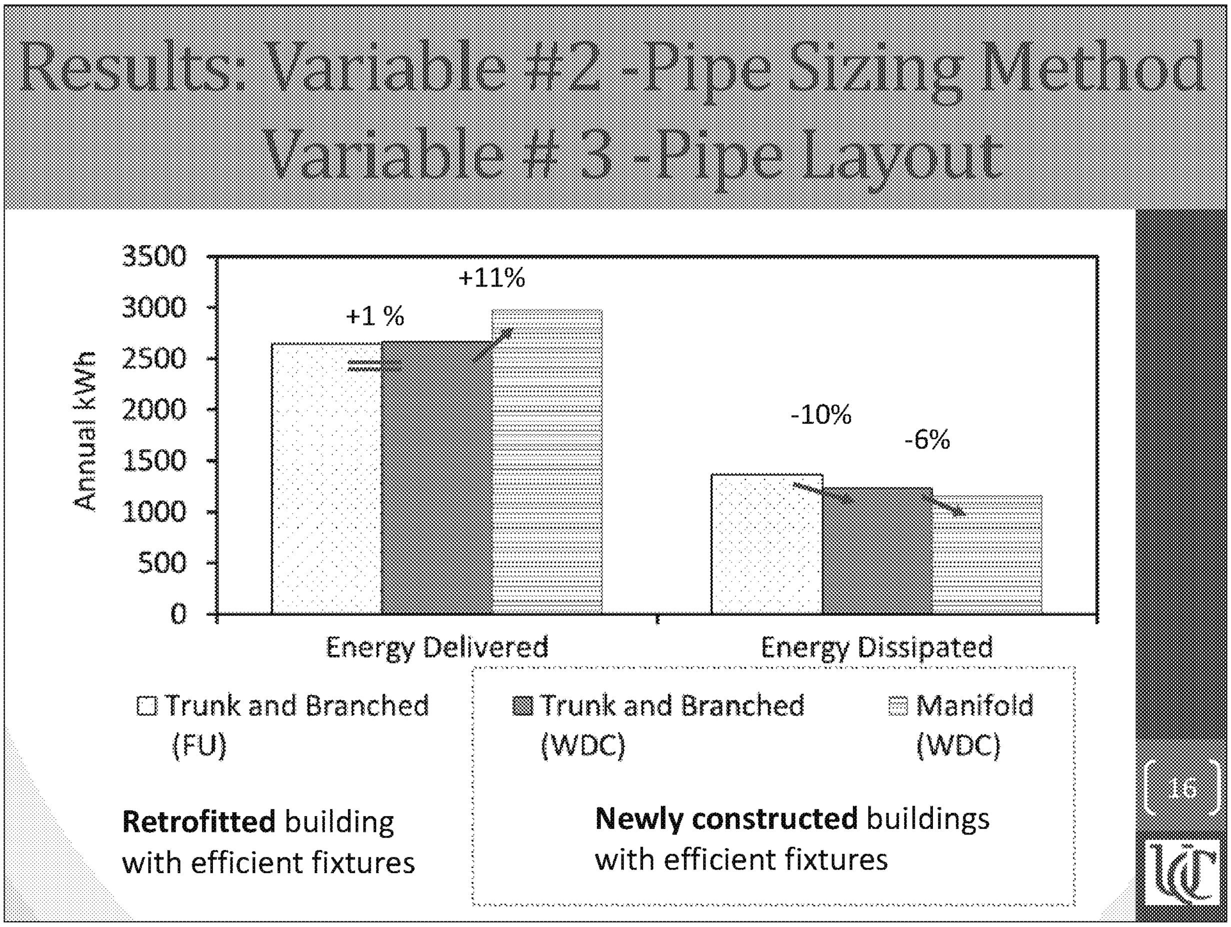
Results: Variable #2-Pipe Sizing Method

	Building Size: Number of Units	Number of fixtures	UPC (FU) Peak Demand (gpm)	UPC (FU) Pipe Size (in)	WDC Peak Demand (gpm)	WDC Pipe Size (in)	Decrease in Peak Demand
	1	9	14.0	1-1/4	9.0	1	36 %
	10	90	65.0	2-1/2	21.3	1-1/2	67 %
	50	450	208.0	5	67.1	2-1/2	68 %

Note:

- Pipe sizes are for hot water flowing at 5ft/sec
- Each is a 2-bath unit has 1 bathtub, 1 clothes washer, 1 tub/shower combined, 1 kitchen sink, 1 dishwasher, 3 bathroom sinks, and 1 shower. (**Efficient** fixtures only)

In terms of demand stress changes



Energy Delivered up is Good – Energy Loss
Retrofitted buildings vs new construction
Annual thermal energy dissipated in pipes 13% decrease due to pipe size 6% decrease due to pipe layout

Results: Relative Residence Time

Case	Pipe Sizing Method - Fixture Efficiency	Relative Residence Time
A	FU Method - Inefficient Fixtures	1.00
B	FU Method - Efficient fixtures	1.43
C	WDC Method - Efficient Fixtures	1.19

(Trunk and Branched Layout)

17

Longer residence times are undesirable since it can promote bacterial growth with reduction in residual chlorine

Residence time is the ratio of the total pipe volume to the mean household demand.

Conclusion

- Lutz *et al.* (2014) – Less than half of the hot water drawn arrives at a fixture. TRUE
  - Hot water pulse duration: about 80% < 1 minute
  - Hot water pulse intensity: about 77% < 1 gpm

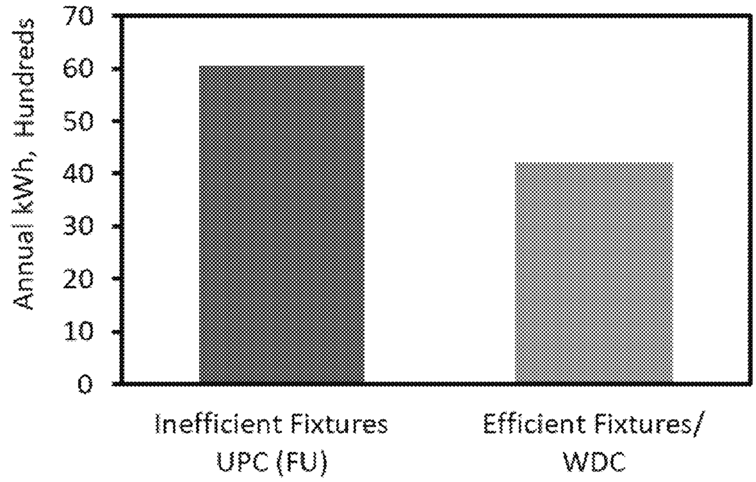
- Sizing pipes with the WDC method would:
  - Reduce the amount of water between the heater and a fixture,
  - Improve water and energy savings in residential buildings

18

The generation of realistic hot water pulses at individual fixtures using MATLAB and the simulation of temperature changes within pipes in EPANET gives us further insight to better understand the water/energy implications.

Conclusion

Efficient fixtures and right sized pipes in a 2-bath single family home resulted in a 30 % reduction in annual hot water energy consumption



Old home with **inefficient fixtures**

Newly home with **efficient fixtures**

19

Old building & inefficient fixtures vs New Construction & efficient fixtures

Acknowledgments

Ohio Water Development Authority

USGS
science for a changing world

This work was supported in part by a grant from the Ohio Water Development Authority for project 2016OH506B entitled:

Improved Estimates of Peak Water Demand in Buildings: Implications for Water-Energy Savings

Also matching support in the form of residential water use data was provided by The International Association of Plumbing and Mechanical Officials (IAPMO) and from a Graduate Scholarship provided by the University of Cincinnati.

IAPMO®
International Association of Plumbing and Mechanical Officials

UC

Questions ?

Omaghotu@mail.uc.edu